SOME METEOROLOGICAL ASPECTS OF THE ICE PATROL WORK IN THE NORTH ATLANTIC.

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Next spring will complete 10 years of ice patrol service in the north Atlantic. During this period scientific investigation of the ice regions has been carried on with the object of increasing our general knowledge of these regions, and also of securing a more effective management of the patrol. Up to within a few years the behavior of ice in the Atlantic was a matter of conjecture. To-day charts are available showing the drift of bergs from the time of leaving the Labrador coast, the courses followed by these bergs being as carefully plotted as the track of a ship. Conditions are subject to much variation from year to year. Some years produce large quantities of ice; other years bring scarcely any. In some years the ice is held up in high latitudes; in others it drifts far south. Until now little time has been devoted to this aspect of the problem. The causes of variations in oceanic circulation, and similarly the behavior of ice from year to year, may be attributed to several factors. The meteorological aspects affecting the movements of ice will be considered later, but before taking up that matter a brief description of the International Ice Patrol Service may be interesting.

Ice which drifts south into the Atlantic every spring constitutes a great menace to steamships plying between Europe and the United States. In the days of slow steamers most of the vessels followed a great circle course between the two continental ports, which carried them through the ice zone a large portion of the year. Since the advent of the large and fast passenger steamers agreements have been entered into whereby definite routes have been established to the southward of the normal ice zone.

If the ice zone were fixed nothing further would be required to assure reasonable safety along the routes, but, as previously indicated, the limits of the ice fields and the bergs vary considerably in location as well as in season, and consequently a vessel might sail on a course that was clear at the time of her departure but collide with ice which had drifted into her path when she reached the vicinity of the Newfoundland Banks.

The establishment of the ice patrol followed directly the *Titanic* disaster, when the then largest ship afloat was sunk on the night of April 14, 1912, by striking an iceberg off the tail of the Great Bank of Newfoundland. In November, 1913, an international convention met at London, and among other subjects discussed the practicability of patrolling the ice regions. It was agreed to establish a permanent International Ice Patrol Service and the United States Government was invited to undertake the management of the service; the expense to be divided among the signatory powers in proportion to the amounts of their respective ship tonnages.

The work has two aspects: First, and of the utmost importance, is the determination of the variable limiting lines of menacing ice, and the dissemination of the information for the guidance of shipping; secondly, and coordinately with the first, is the making of such oceanographical and meteorological observations as will determine the causes of these variations, thereby increasing our knowledge to insure means of greater safety for life at sea.

A continuous patrol is maintained by two United States Coast Guard cutters capable of keeping at sea in all kinds of weather, each one alternately taking a two weeks' tour of duty and then being relieved by the other. When the ice scout approaches the ice region, it collects all information from near-by vessels and proceeds to search the area south of latitude 43° for signs of ice. It is the duty of the patrol to maintain contact with the southern, eastern, and western limits of ice as they vary in position throughout the season, and to broadcast this information to all approaching ships.

It can be seen from this duty as briefly described that a thorough knowledge of ice movements is absolutely necessary. In conjunction with its scouting duty, the ice patrol secures scientific observations relating to the area. Daily reports also are forwarded to the United States Weather Bureau. Previous scientific investigation of the vicinity of the Newfoundland Banks is negligible, except for the Murray and Hjort expedition on the *Michael Sars*, 1912, and the *Scotia* cruise, 1913, Mathews. Vessels' logs possess a large amount of data, but it is not easily accessible and is limited to the ocean surface. No true picture of oceanographical conditions can be obtained without consideration of the subsurface.

The three great ocean currents in the northwest Atlantic are well known, viz, the East Greenland, the Labrador, and the Gulf Stream. The East Greenland current is an overflow from the north polar basin of an accumulated mass of fresh water which has been discharged from northern Eurasian rivers and augmented during the summer by the water from melted ocean ice. The escape is southward past Jan Mayen along the east coast of Greenland, where the current bears great masses of heavy sea ice. The number of bergs is comparatively small, due to the scarcity of glaciers along the east coast. The East Greenland Current rounds Cape Farewell and continues northward along the west coast of Greenland to 65° N., where it begins to throw off branches westward to the Labrador Current. From 70° N. a northerly current is found along the coast as far as Cape York, where it turns sharply south in the east branch of a southerly current.

The polar drift, which has its source north of Smith's Sound, is made up of two branches, an eastern branch, consisting of the current just described, and a western branch which flows southward close to the American coast, being augmented by tributaries from Lancaster Sound, Jones Sound, etc. In Davis Strait the east and west branches join, forming the Labrador Current. Tracing the Labrador Current in its southern extension we find it floods the northern part of the Great Newfoundland Bank, a small branch escapes to the westward through the "Gully" under the Newfoundland headland. Greater quantities spread eastward in expansive surface layers, while the middle branch continues its flow along the east slope of the Great Bank. When the polar currents are swelled, arctic water spreads in over the Bank and across the southern end, otherwise the area over the Bank presents a characteristic identity that is at no time engulfed by either Labrador Current or Gulf Stream. The Labrador Current flows southwesterly around the

Tail of the Bank and impinges on the Gulf Stream which is flowing east past the Tail. The Gulf Stream, after it passes the Bank, spreads out in fan shape into several swirling bands and expansive ocean drifts. Upon meeting the Gulf Stream, the Labrador Current is frictionally arrested, then turned in toward the Stream, and lastly pulled along in an easterly flow parallel with the Stream, with a consequent interdigitation of polar and tropical water at the Tail of the Bank in the form of varied mixing eddies.

The statement that the Labrador Current is arrested in its flow and turned back parallel to the Gulf Stream is at variance with the views of many authorities who claim that the Labrador Current sweeps southwesterly across the Great Bank and continues as a cold current with a set down the east coast of the United States as far as Cape Hatteras. Another fact which has been brought out by the oceanographical work of the ice patrol is the lack of evidence to support the belief that the Labrador Current upon meeting the Gulf Stream dives beneath the latter, emerging to the southward. The evidence gathered by the patrol forbids such a view. On the contrary, the tendency of the polar water to spread out on the surface is quite pronounced. One ocean current may dive beneath another at some places in the world, but such is not the case here.

In the consideration of ice, it is necessary to make a distinction between field ice and berg ice. Field ice, formed by frozen Arctic sea water, is under the control of the winds and the surface currents. It is the first ice to drift south, putting in an appearance as early as January and February. At the latter date it often covers the entire area between the Newfoundland coast and the 43d parallel. In March and April it is noted most frequently on the southern part of the Great Bank. In low latitudes it is quickly melted and is by no means as dangerous as icebergs.

The great source of icebergs is the glaciers on the west coast of Greenland, from the region of Disko northward. When released by the breaking up of the field ice in summer the bergs are drifted around by ocean currents until they succeed in entering the Labrador Current. They first appear during March, drifting south along the east side of the Great Bank. During April, May, and June, bergs constitute a menace to steamships in this vicinity.

As stated above, the oceanic circulation and movements of ice are subject to continual variations which are attributed to several underlying factors, viz: (*a*) Meteorological conditions over the north Atlantic and Arctic regions, (*b*) the hydrodynamics of the Atlantic and Arctic basins, (*c*) variations in solar energy. In reviewing some of the literature upon the subject,[1] there is a modern tendency to stress the importance of the potential possessed by large bodies of water of similar character. The theory, briefly stated, is that the basic principle of oceanic circulation originates in the physical changes in water which manifests themselves in movements of a certain kind of a water mass from the region in which it abounds to the region where it is scarce. The volume and velocity of the induced current thus established will be governed by the supply and demand. Meteorological changes are factors in oceanic circulation which cause variations according as they increase or decrease dynamic forces. An example of this is a prevailing off-shore wind across the Gulf Stream that tends to push the surface layers of the Stream, from their normal course, but if this meteorological phenomenon be removed, normal positions are resumed.

In the northwest Atlantic probably the underlying cause of the Labrador Current is hydrodynamic conditions. Seasonal melting of the ice in northern regions causes an excess accumulation of cold fresh water to flood the surface between Greenland and North America. It seeks escape in a southward expansion on the warm saline water of the lower latitudes.

The variations in movements of the surface water are greatly influenced by the circulation of the atmosphere. They follow directly from the seasonal changes. The wind control is determined by the position, form, and intensity of the whole north Atlantic high-pressure area and by the cyclonic area to the northward. If the Icelandic minimum lie to the westward in the Greenland region, during the months of December, January, and February, the period when the field ice breaks loose, it will cause prevailing southwesterly winds which will retard the Labrador Current and tend to hold the ice in the higher latitudes. On the other hand, wind possessing a strong northerly component will tend to augment the Labrador Current and drift the ice south faster and in greater quantity than otherwise. The normal seasonal increase in size and intensity of the north Atlantic high during summer causes strong southwesterly winds which speed up the Gulf Stream. A great amount of warm water is accumulated in the eastern Atlantic basin which escapes to the northeast, even entering the polar basin. The reports recently received from Spitzbergen telling of unusually mild weather and open water where it is normally covered with ice may, if they are reliable, be attributed to a combination of favorable conditions, one of the individual factors being the atmospheric circulation over the north Atlantic.

Another matter of direct importance to the patrol is the probable relation existing between the distribution of the two kinds of ice in the lower latitudes during a given year and the meteorological conditions in northern regions during the previous year. Some work in this line has been done by Dr. Ludwig Mecking (1907)[2] and the conclusions reached are extremely interesting. In brief, these may be stated as follows: The amount of field ice appearing during the season off the Newfoundland Banks is compared with the mean barometric pressure gradient for December, January, and February, connecting two points which lie across the Labrador Current in the vicinity of the Labrador coast. The agreement is astonishingly good. The explanation is simple if we assume that the great source of the field ice is the Labrador coast, and that the gradient is a measure of the amount of off-shore wind which breaks the ice loose and permits it to drift southward.

The number of icebergs in any year in the north Atlantic is determined by the barometric gradient over the birthplace of the bergs in west Greenland during the previous summer. The assumption is that off-shore winds will drive a great number of bergs westward into the southerly current, thus preparing for a year unusually rich in bergs in lower latitudes. On-shore winds, on the other hand, tend to cause a poor ice year.

An attempt is being made, using the much more accurate data regarding icebergs in the vicinity of the Newfoundland Banks, to determine a possible relation be-

[1] Sandstrom, W.: "Canadian Fisheries Expedition, 1914-1915," pp. 221-291.
Pettersson, O.: "Connection between Hydrographical and Meteorological Phenomena," Quart. Jour. Roy. Met. Soc., July, 1912, pp. 123-191.
Dickson, H. N.: "The Circulation of the Surface Waters of the North Atlantic," Phil. Trans. Roy. Soc., London, 1906, vol. 196-A.
Bjerknes, V. E. K.: "Dynamic Meteorology and Hydrography," Carnegie Institute, Washington, 1910-11. Pub. No. 88.

[2] Mecking, L.: "Die Treibeiserscheinungen bei Neufundland," Annalen d. Hydro., Berlin, 1907, pp. 348-396.

tween the ice and the meteorological conditions based upon the last 10 years of the ice patrol work. Difficulty has been experienced in securing meteorological records from critical points on the Greenland and North American coasts.

It is unfortunate that there are not several year-round meteorological stations in northern regions. Besides the advantage which might be derived from their records, as just indicated, they might also serve as ice observation posts. If a station could be located somewhere along the side of the arctic drift where it sweeps in close to the shore, for instance at Cape Dyer, Baffin Land, it could serve the double purpose of a meteorological station and an ice observation post. The situation may be likened to that of a river. Flotsam observed upstream in the current will later appear at the river mouth. In this case the Labrador Current is the river whose mouth is in the vicinity of the Great Bank of Newfoundland; the flotsam is the icebergs. It takes approximately five months for a berg passing Cape Dyer to appear south of the 45th parallel. If the record of the number of bergs, with dates of passing Cape Dyer, were known to the ice patrol and the Hydrographic Office, long range forecasting of ice conditions in the North Atlantic would probably be possible. It would prepare us to meet and deal with a situation about which to-day we lack advance information.

POLAR ICE-DRIFT AND SUN SPOTS.

By GEORGE NICOLAS IFFT, American Consul.

[Bergen, Norway, Dec. 6, 1922.]

An interview with Dr. Adolf Hoel expressing doubt of the possibility of Amundsen's plan for drifting over the North Pole in the *Maud* with the supposed drift of the polar ice is attracting much attention throughout Norway and causing considerable discussion in the Norwegian press. Doctor Hoel, who is lecturer on geology at the Christiania University and who during the summer headed a government research expedition to Spitzbergen and the surrounding waters (see my report on "The Changing Arctic," transmitted under date of October 10, 1922), suggests that such drift over the pole would be possible, if at all possible, some years hence, upon the theory that the polar region is subject to fixed periodic changes and that such period affecting ice conditions is one of from 10 to 11 years closely connected with the known sun-spot periods.

Doctor Hoel states that the fact of the ice drift from the northern coasts of Asia and America across the pole to the strait between Spitzbergen and Greenland and then south along the east coast of Greenland has been shown by the drift of the *Jeanette* and other vessels. Amundsen's experience last year, however, seemed to indicate that the ice drift is subject to variations. At all events, the *Maud* did not succeed in getting into the drift because of unfavorable ice conditions and Doctor Hoel argues that it is reasonable to assume, either, that the exceptionally favorable ice conditions now prevailing at Spitzbergen are due to the fact that the polar current is weak and that the unfavorable ice conditions on the Asian and American north coasts are due to such cause or, that the ice in those regions actually moves in an opposite direction from that in which it has been believed to move.

Dr. H. T. Hesselberg, director of the Norwegian Meteorological Institute, discussing such suggestion, states that there can hardly be talk of a 10 or 11 year ice period in the polar seas without having submitted such theory to a thorough investigation and without a thorough study of the comparatively scanty material at hand. In regard to a relation between polar ice conditions and sun-spot periods, he said that the influence of sun spots is felt in so many conditions, among them atmospheric conditions, that it is not impossible that they also play their part in ice conditions about the pole. At the same time, he considers Doctor Hoel's statement of the utmost interest, as he is thoroughly familiar with conditions in that section of the world.

A REVIEW OF GEOPHYSICAL MEMOIRS NO. 19.[1]

By ALFRED J. HENRY.

[Weather Bureau, Washington, D. C., Dec. 28, 1922.]

The latest *Memoir* of the British Meteorological Office is a welcome contribution upon a subject of very great interest from both a theoretical and a practical viewpoint. It is peculiarly appropriate that this discussion of tropical cyclones should come from the English Meteorological Office, since it was Piddington, an Englishman, who first gave the name cyclone to the revolving storms of the Bay of Bengal more than half a century ago.

The raison d'être of the *Memoir* was an inquiry originating with the Colonial Secretary as to the visitation by tropical storms to the various dominions beyond the seas. Naturally the Meteorological Office was called upon to prosecute the inquiry. Obviously one of the first steps was to assemble in convenient form the enormous mass of widely scattered material from the original sources. The accomplishment of this object was entrusted to Mrs. E. V. Newnham, M. Sc., a member of the professional staff of the forecast division. How well she accomplished this difficult task may be seen by a perusal of the 102 closely packed quarto pages of text and charts.

The *Memoir* includes, in addition to the material collected by Mrs. Newnham, an introduction by Sir Napier Shaw, to which reference will be made later, and a short discussion by Dr. Harold Jeffreys on "Theories on the Origin of Tropical Cyclones."

The observational material is presented in four sections, each one dealing with those portions of the great oceans which are subject to visitation by tropical cyclones. These are:

(1) North Atlantic: A. West Indian Hurricanes.
B. Squalls and Tornadoes of West Africa.
(2) Indian Ocean: A. Cyclones of the Bay of Bengal and the Arabian Sea.
B. Cyclones of the South Indian Ocean.
(3) Pacific Ocean: A. Typhoons of the North Pacific.
B. Revolving Storms of the South Pacific.

The material is presented in great detail with many rather full extracts from the original papers. Thirty-three full page plates with numerous inserts illustrate the paper.

[1] Hurricanes and Tropical Revolving Storms, by Mrs. E. V. Newnham, M. Sc. With an introduction on The Birth and Death of Cyclones. By Sir Napier Shaw, F. R. S. pp. vi. 122 illus. H. M. S. O., 1922. Price 12s. 6d.